

Barrier Coatings and Stability of Thin Film Solar Cells

**2nd Quarterly Report - Phase III:
December 1, 2006 -- February 28, 2007**

NREL Subcontract: 48027

Subcontractor: Pacific Northwest National Laboratory

Principal Investigator: Larry C. Olsen

1. OBJECTIVES/APPROACH

The key objectives of the program are to develop low cost barrier coatings for CIS and CdTe solar cells and to develop an improved understanding of the effects of water on the stability of these types of cells. The scope of this work entails investigations of multilayer, barrier coatings for CIS and CdTe thin film solar cells, and studies of stability issues, particularly those related to moisture ingress. Investigation of barrier coatings on SSI and CSU devices will continue in an effort to establish effective approaches to encapsulate CIS and CdTe modules. Studies will also be directed towards issues concerning cost of the coating process. The program will be structured into three major tasks: (1) Barrier coatings and stability studies for CIS Solar Cells; (2) Barrier coatings and stability studies for CdTe solar cells; (3) Low cost coating process development.

2. PROGRESS FOR THIS REPORTING PERIOD

Due to the interest in thin film PV based on CIGS, we are going to focus our barrier coating studies on areas of importance to CIGS solar cells in the remaining months of this program. Our investigations to date were based on Shell Solar, Inc. (SSI) cells and mini-modules. We found that these cells were extremely vulnerable to damp heat effects. These devices are no longer available to PNNL due to the closing of the Chatsworth CIGS operation. However, we have a supply of 2 in. x 2 in. mini-modules that were used in recent studies that are discussed in this report. Moisture ingress is apparently not an issue if modules are fabricated with glass-to-glass construction. It is clear, however, that CIGS cells and modules fabricated on flexible substrates must have an effective barrier coating. As a result, we plan to concentrate on establishing baseline information concerning the effects of damp heat on CIGS.

3. DAMP HEAT STUDIES WITH SSI CIGS MINI-MODULES

Previous studies on bare cells were conducted under damp heat conditions of 60°C/90%RH. Studies carried out for this report were done at 85°C/85%RH. The circumstances for the study were not ideal in that the SSI 2 in. x 2 in. mini-modules had been exposed to ambient conditions for approximately 3 years prior to the study. Nevertheless, some significant results were obtained.

3.1 Current-Voltage Characteristics

Figure 1 gives characteristics for a typical SSI 2x2 mini-module at beginning-of-life. AM1 efficiencies were typically in the 8 to 10 % range. Data are given for a device before and after being stressed @ 85°C/85%RH for 70 hours. As indicated, the 2x2 mini-module had been in ambient conditions for approximately three years. During this time the sheet resistance of the ZnO TCO increased significantly, which caused a very large decrease in fill factor. The fill factor decreased even further as a result of the accelerated testing at 85/85. It is clear from these studies that the ZnO sheet resistance increases significantly as a result of the damp heat conditions. Values of sheet resistance

are given in Table 1. The effect of moisture on CIGS sheet resistance is generally known, but past PNNL studies suggested that the junction properties also degrade as a result of damp heat. The large values of sheet resistance make it difficult to carry out I-V analyses to determine junction parameters. However, PL measurements of effective lifetime were carried out to determine qualitative changes in carrier transport properties. Figures 2 and 3 give results of photoluminescence studies taken before and after stress. The PL spectra shown in Figure 2 suggest an apparent band edge shift to a slightly larger value as a result of moisture ingress. PL lifetime data are given in Figure 3. These

Table 1 --- ZnO Sheet Resistance

Mini-Module Status	ZnO Sheet Resistance
After 3 Years under ambient conditions	4 ohms/sq
After 70 hours at 85/85	100 ohms/sq

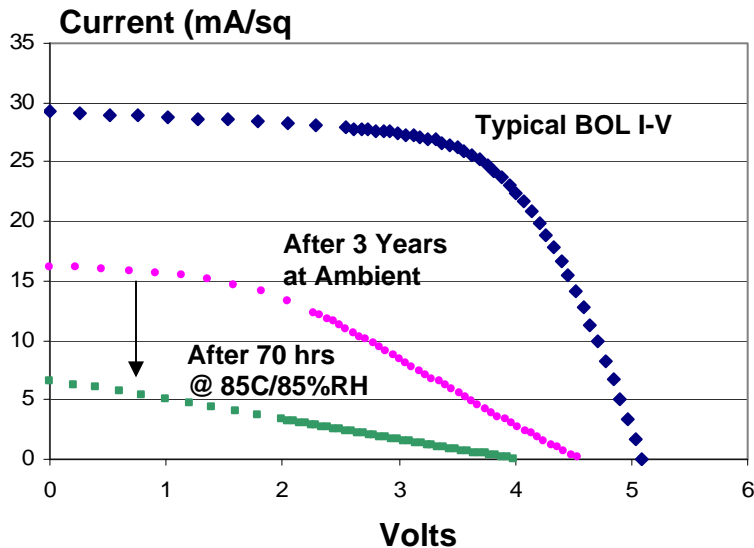


Figure 1. Current-voltage characteristics for 2x2 mini-modules. BOL refers Beginning-of-Life.

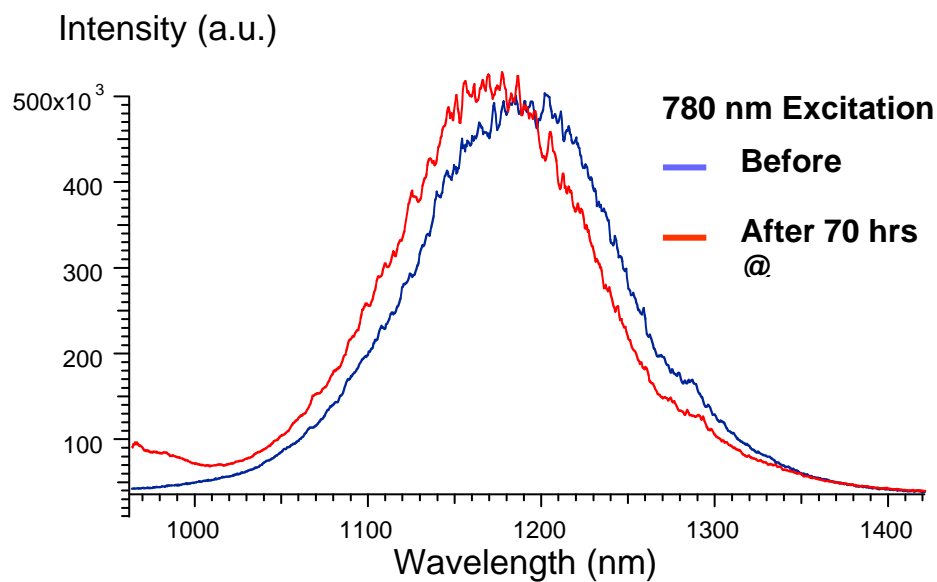


Figure 2. PL spectral data taken for a 2x2 mini-module acquired before and after stress at 85°C/85%RH for 70 hours.

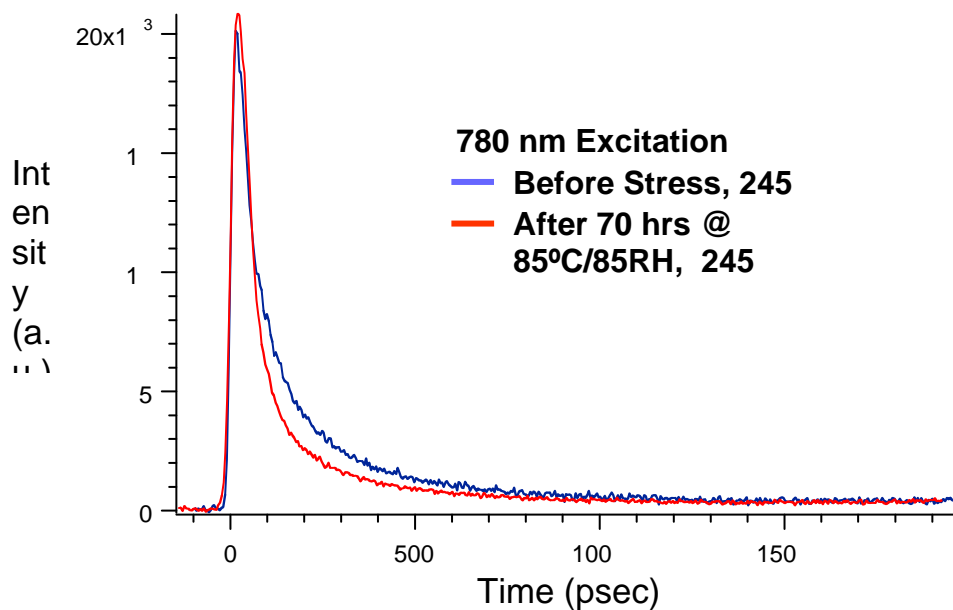


Figure 3. PL lifetime data taken for a 2x2 mini-module acquired before and after stress at 85°C/85%RH for 70 hours.

results are quite interesting. The PL lifetime was basically unchanged as a result of moisture ingress that occurs from the damp heat stress. Thus, it appears that moisture did not affect the minority carrier lifetime, which is related in some manner to the PL lifetime. I-V analyses carried out in earlier work indicated that junction properties (J_0 and 'A') changed as a result of stress. In this case, however, it appears that the carrier transport properties did not change significantly after the three years at ambient conditions.

One result of this brief study that is consistent with previous studies, is that damp heat causes a significant reduction in the sheet conductance of the SSI ZnO TCO. SSI grew their ZnO by CVD. It may be that other growth approaches will yield ZnO TCOs that are less sensitive to damp heat. We have evidence that sputtered ZnO is more resistant to effects of moisture. Regardless of the approach used, however, it seems clear that in order for CIGS on flexible substrates to constitute a successful approach to thin film PV, the cells must have an effective barrier coating.